Calcifying algae as key players in climate models

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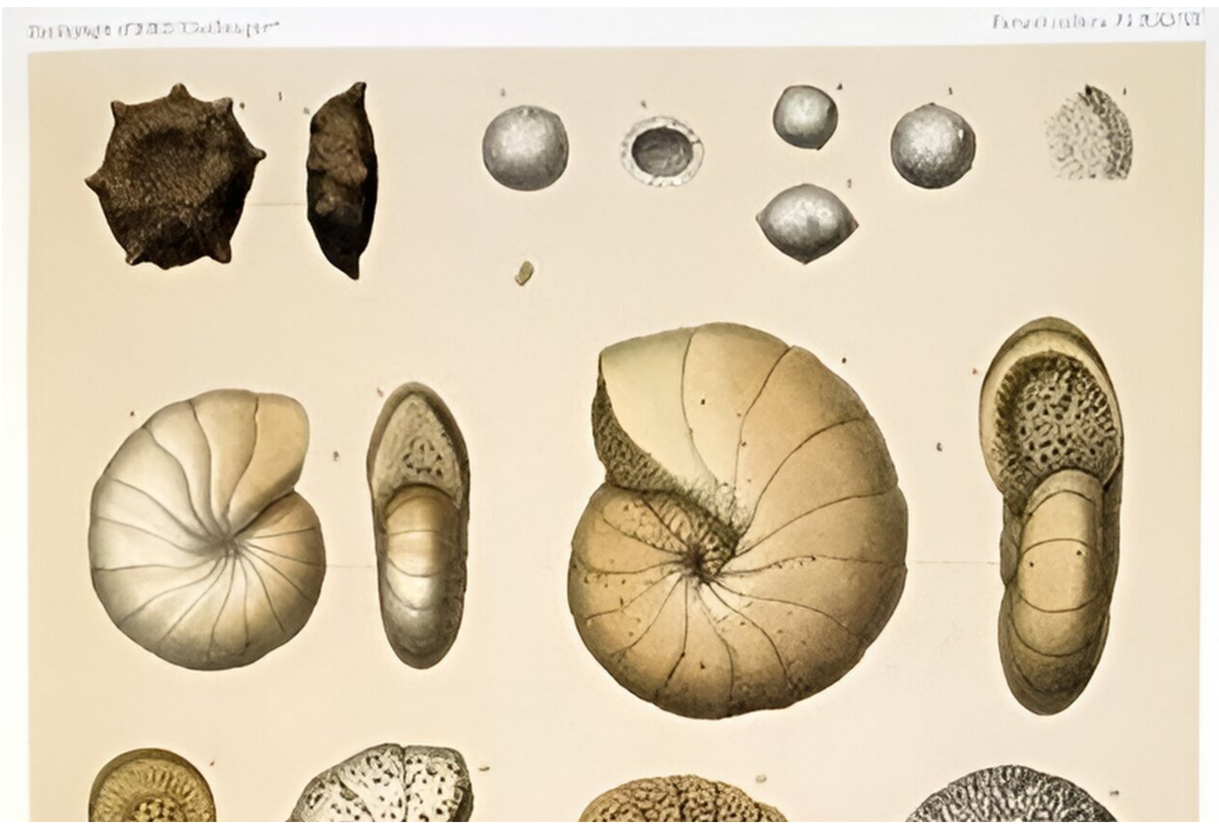


Drawings from the 19th century showing foraminifera that were collected during an oceanographic expedition. The species depicted here live at the bottom of the ocean and add chambers of calcium carbonate to their shell during their lifetime. From: 'Voyage of H.M.S. Challenger 1873-1876. Zoology Vol. 9 Foraminifera, 1884, Wyville Thomson.' Credit: 'Voyage of H.M.S. Challenger 1873-1876. Zoology Vol. 9 Foraminifera, 1884, Wyville Thomson.'

Over the past 500 million years, different single-celled organisms in the oceans have discovered at different times and also under very different conditions how to build a 'shell' around their single cell. "Six different strategies under just as many different environmental conditions," says researcher Lennart de Nooijer.

"If we understand these mechanisms better, we might also be able to predict how the calcium balance in the oceans is going to change under the influence of the changing climate. Even though they are tiny, the seemingly endless quantities of these single-celled organisms in the oceans have an impact on the carbon cycle of the entire planet that can actually be measured."

The single-celled organisms De Nooijer studies are called foraminifers. They are algae named after the little holes—"foramina" in Latin—that many species have in their tiny shells. "Those calcareous shells appear to be a typical case of so-called convergent evolution," De Nooijer discovered. The findings are published in the journal *Earth-Science Reviews*.

"The best-known example of convergent evolution is the wings that both birds and insects have developed during evolution. Both groups lack a common ancestor with wings, but in evolution both 'came up with the good concept' to fly with wings, completely independently of each other. Similarly, six different groups of foraminifers once started making calcium shells around their cell."

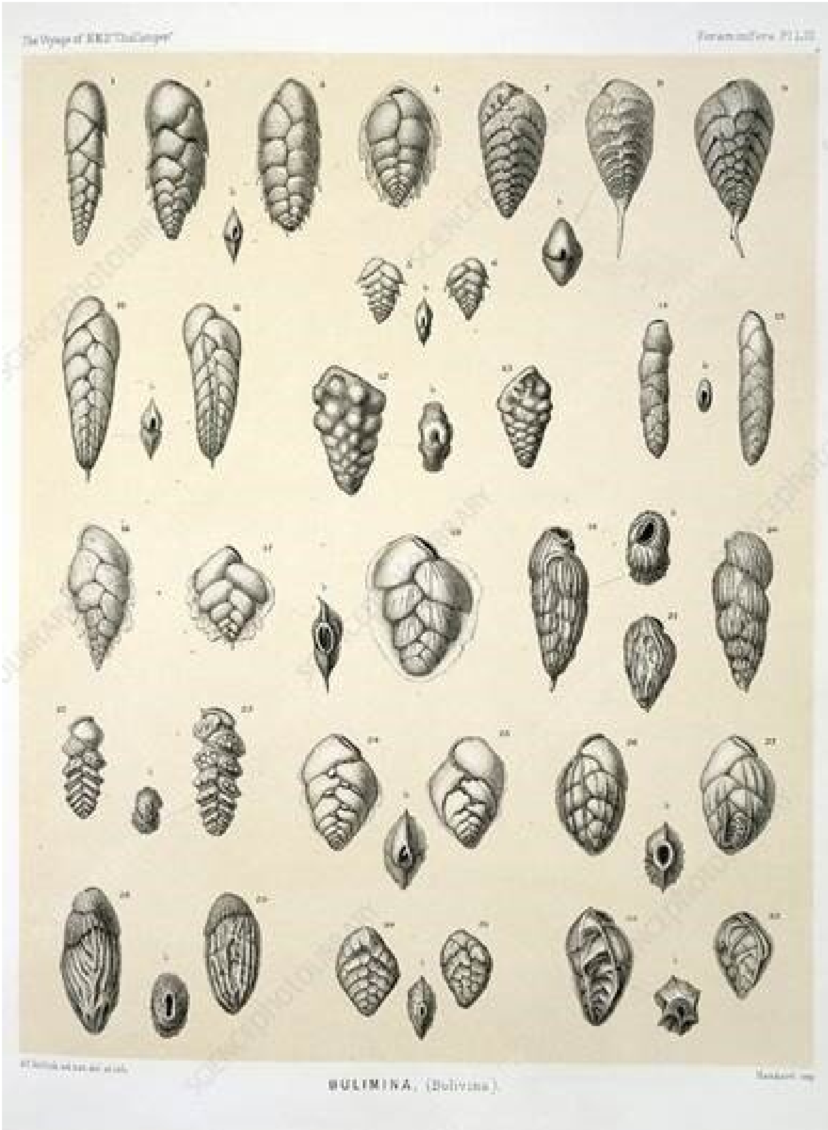
From porcelain to chunks of lime

If you look closely, you can see essential differences between the six groups of foraminifers in the lime shells. De Nooijer says, "The miliolids make shiny shells that almost look like porcelain. The nodosarids, on the other hand, make relatively coarse structures that look like porous blocks of lime under the microscope. The carterinids stick endless ovals together, which again look beautiful under the microscope."

Within a group, the variation can also be enormous. "The rotalids, for example, vary from miniature snail shells to a kind of fan, but all around a single cell."

Why foraminifers make those calcareous shells is up for debate. "There is this hypothesis that it has to do with the discharge of calcium, which is very abundant in seawater, but which any living creature doesn't want to have too much of in their cells. Maybe these algae discharge their excess calcium in the form of chalk," says de Nooijer.

"But in the meantime, I think that the algae also benefit from that calcium shell. In distant evolutionary history, for example, there was a foraminifer that could grow as large as ten centimeters with its single cell. If you grow bigger, you may have an evolutionary advantage over other algae, but that only works if you have a sturdy external skeleton to support you," De Nooijer says.



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Apart from answering the interesting "why," De Nooijer sees a very practical application of this knowledge about the calcareous shells of his algae.

"By scouring all the literature on these organisms, I found six moments in history when foraminifers started forming shells. The amounts of calcium, CO_2, magnesium and other chemical substances in the water, as well as the temperature, varied considerably between those six periods in history. Thus, by looking at the different foraminifers in a particular layer of sediment, we can learn a lot about the environmental conditions at a particular time."

"But conversely, we can also try to predict how the foraminifers will change under changing conditions, for example due to increasing temperatures and CO_2 in the ocean water."

De Nooijer is not at all worried about, for example, the upcoming extinction of certain foraminifers due to the changing climate. "But changing the composition of all these algae, does have a huge impact on the calciforous and CO_2 balance of the oceans. For example, while forming shells, the algae themselves emit CO_2. So, we will never fully understand the complete carbon accounting of the oceans if we don't understand how these foraminifers deal with calcium and CO_2."

In the past, with the help of laboratory experiments, more attempts have been made to understand the influence of CO_2, temperature and calcium on foraminifers, and thus on the entire ocean. "These experiments always produced very contradictory results," De Nooijer observed. "Now I better understand why: there are very different strategies within this one group of algae that all require their own conditions."

The penny didn't drop for de Nooijer until he was forced to work from home during the COVID pandemic. "Only then did I have the peace and time to lump together all the literature on this group of algae and look for connections."

More information: L.J. de Nooijer et al, 500 million years of foraminiferal calcification, *Earth-Science Reviews* (2023). DOI: 10.1016/j.earscirev.2023.104484

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